

CO-OPERATIVE RESEARCH AND DEVELOPMENT FOR ADVANCED MATERIALS IN ADVANCED INDUSTRIAL GAS TURBINES

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Acknowledgement

- **Research sponsored by the U.S. Department of Energy, Under Contract # DE-FC02-00CH11048**
- **Program Manager: Ms. Jill Jonkouski
Chicago Operations Office**

Key Partners in the program

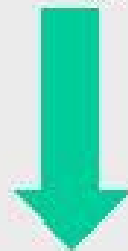
- Major coating vendors:
 - Turbine Airfoil and Coating Repair (TACR), Middletown, NY
 - Engelhard Corporation
 - Praxair Surface Technologies
- Major raw materials suppliers
 - Praxair Surface Technologies
 - Transtech Corporation
- Materials Property and coating performance evaluation
 - Oak Ridge National Laboratory
 - University of Cincinnati
 - Westinghouse Plasma Center
- Host engine customer site for rainbow engine test

Talk Outline

- Program Objectives
- Introduction
 - current TBC limitations and proposed solutions
- Technical approach to incorporate advanced TBC technology into our IGTs
 - a low risk, high pay-off strategy
- Accomplishments to date
 - Optimized deposition trials and key materials properties
 - High heat flux testing results
 - Engine test results

Program objective

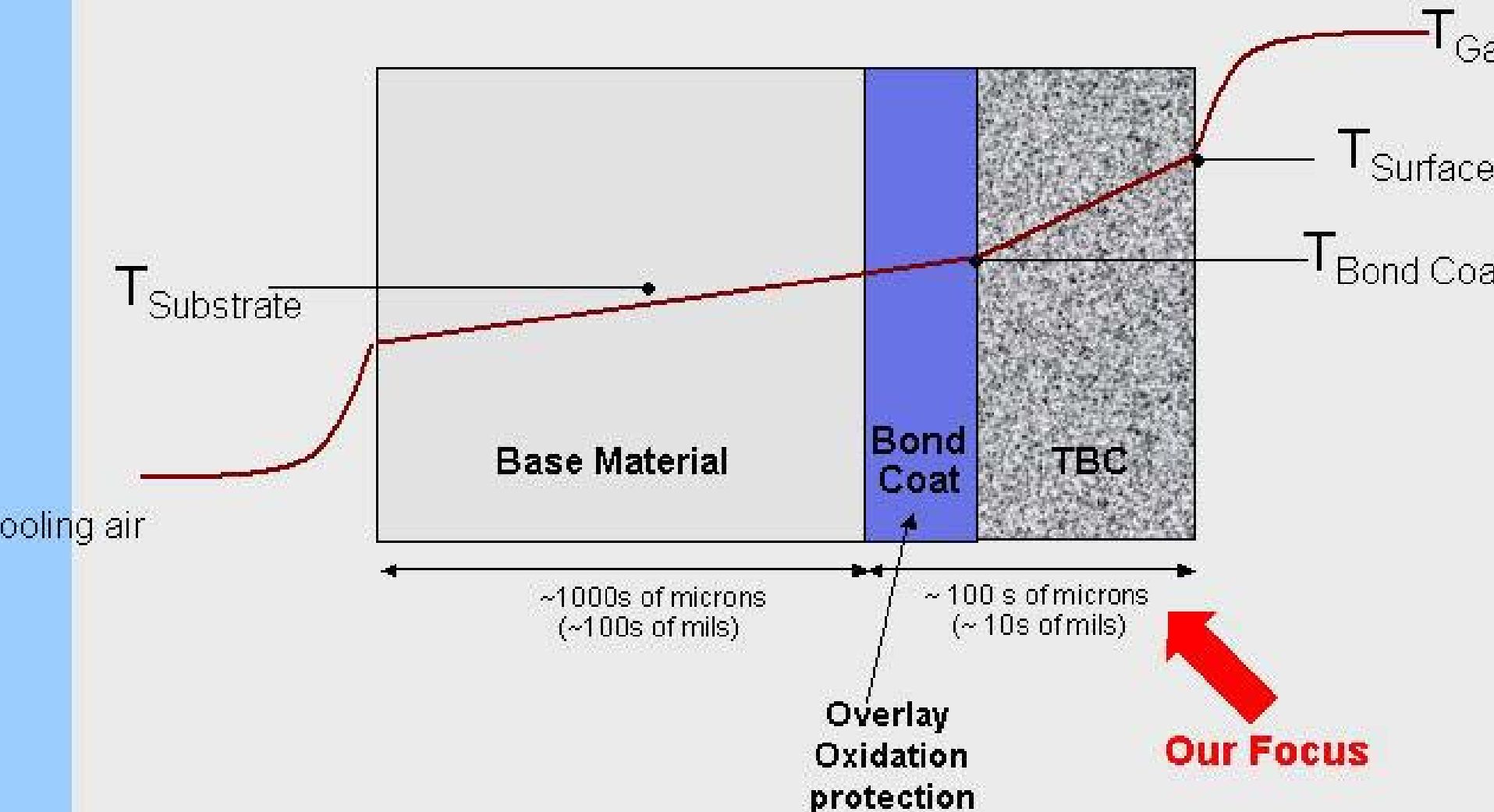
A 3-year program, to transition advanced TBC concepts from the development phase to an engine tested coatings technology



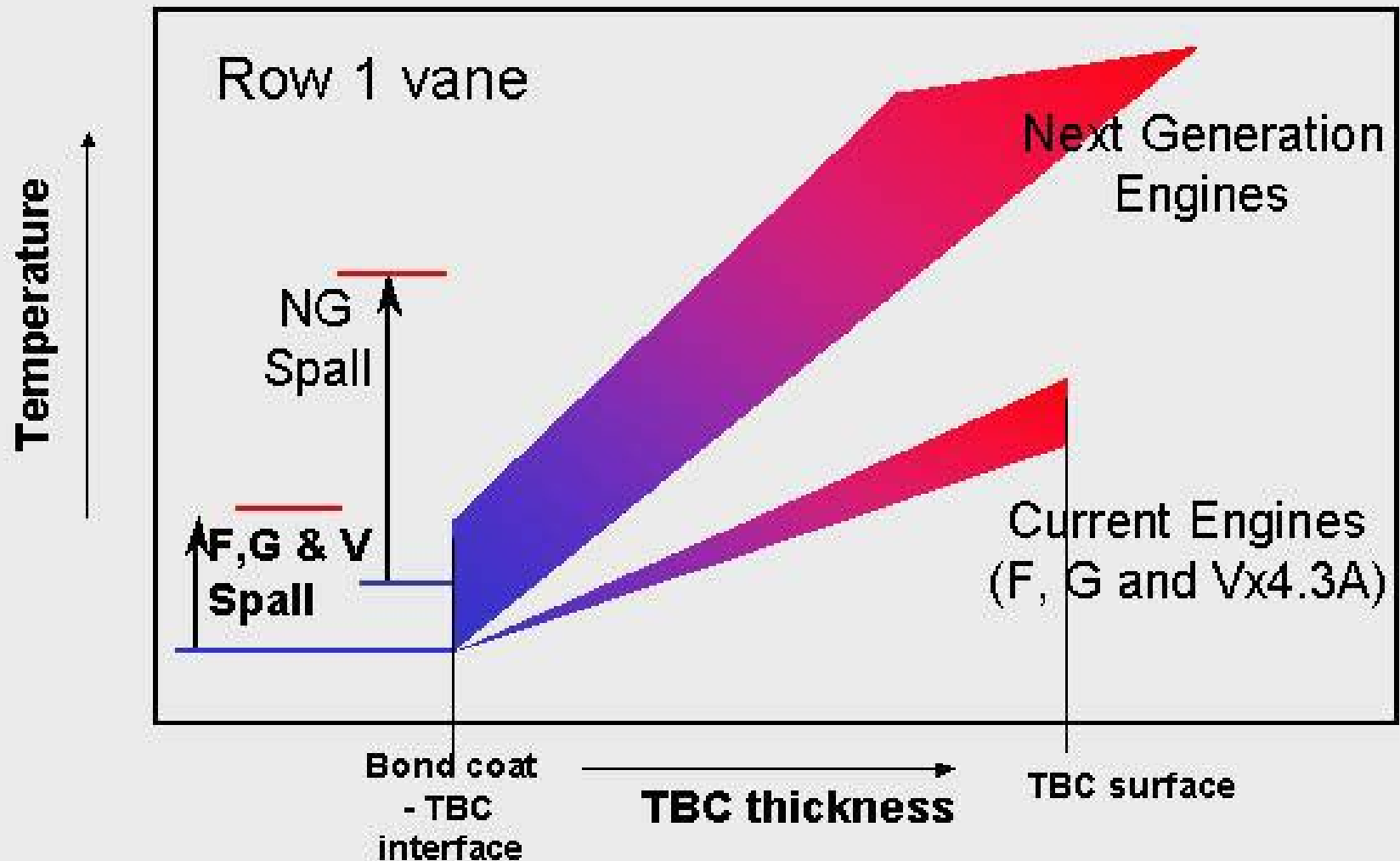
- Increased engine efficiency
- Higher reliability and durability
- Lower electricity cost
- Increased component life
- Reduced emissions

Establish an enabling technology for the future

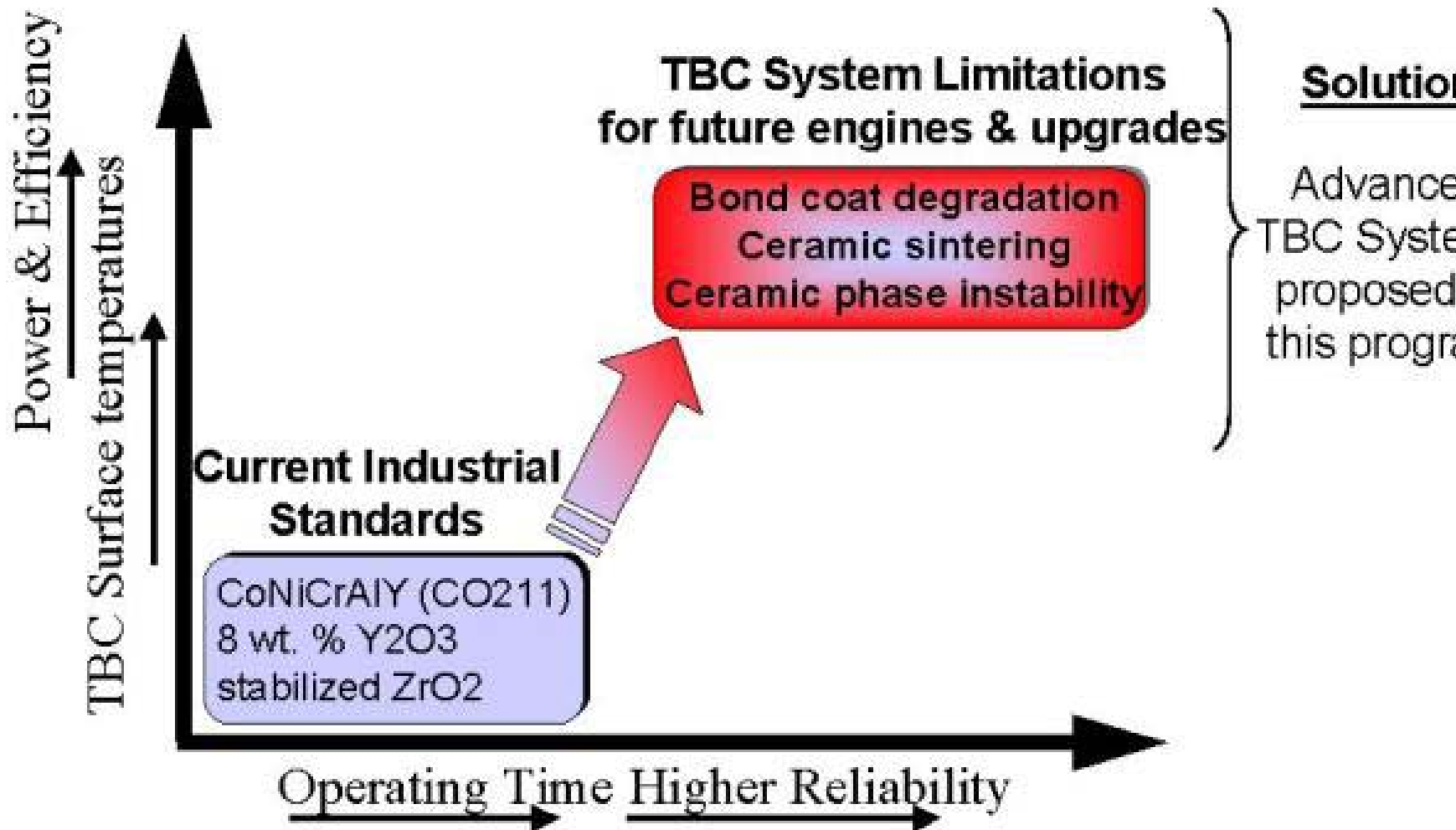
Coatings provide both thermal and oxidation protection



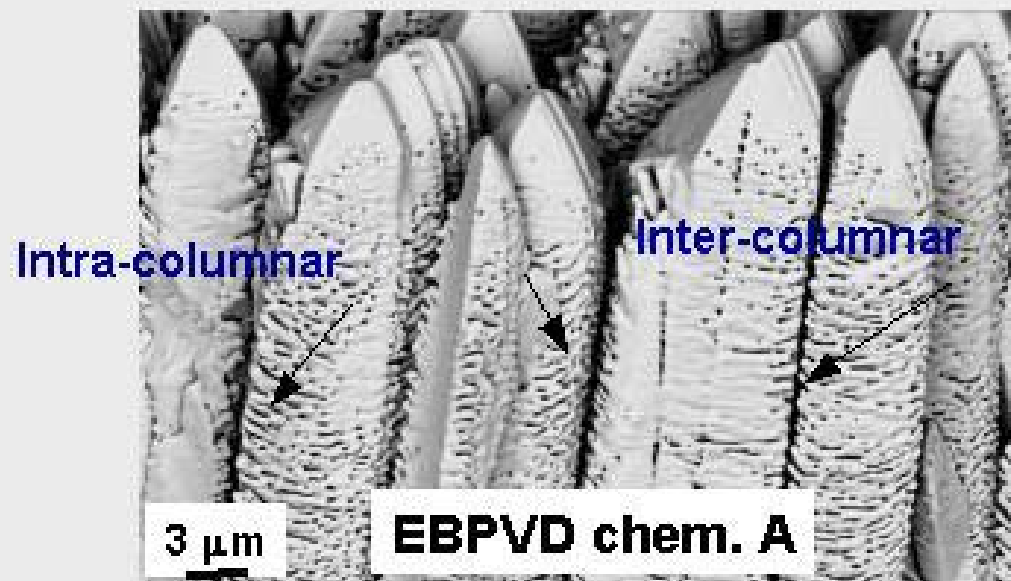
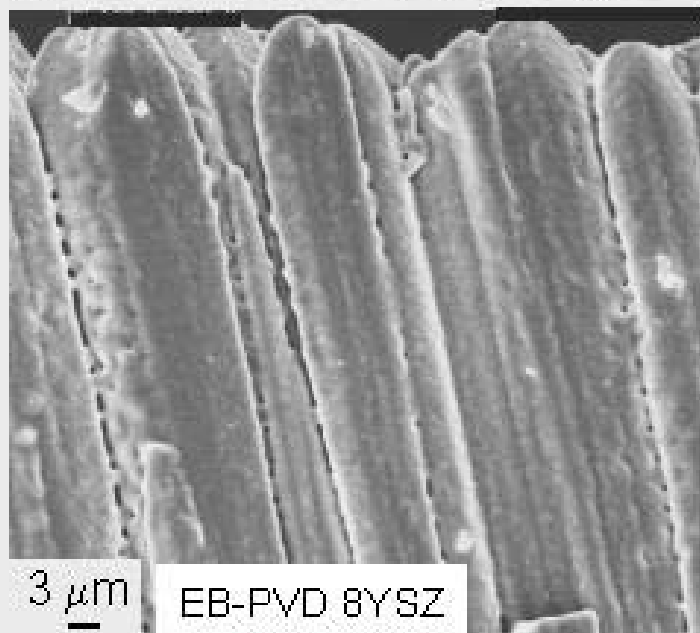
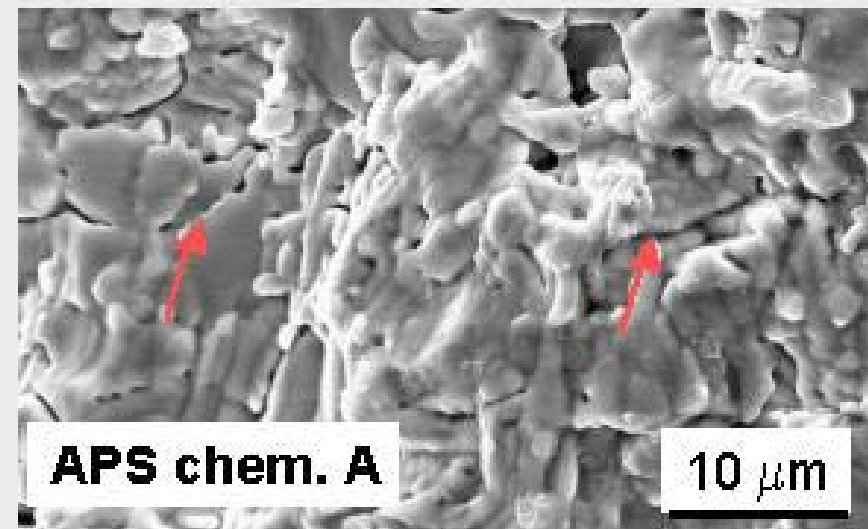
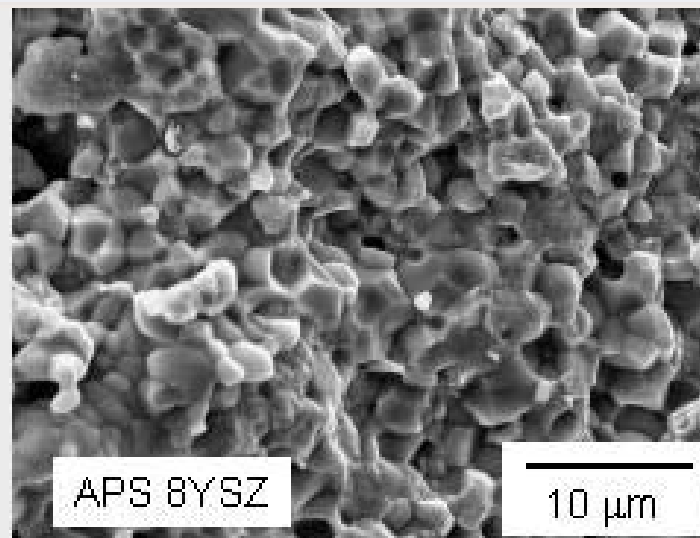
Next Generation engines require advanced TBCs with increased temperature capability



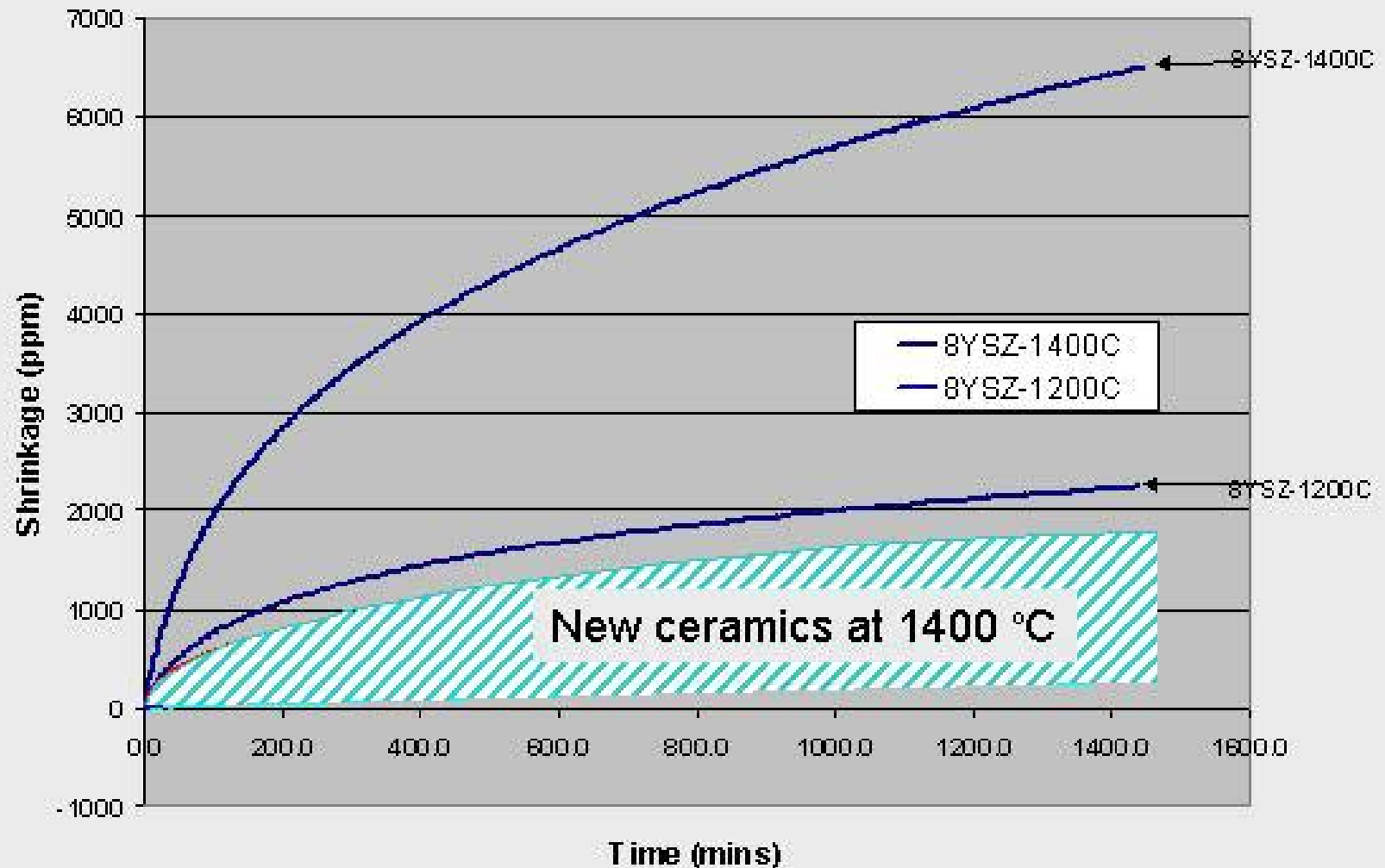
Advanced TBCs can overcome the limitations of the current 8YSZ TBCs



Superior sintering resistance, relative to 8YSZ, is observed for all ceramic compositions deposited both by APS and PVD

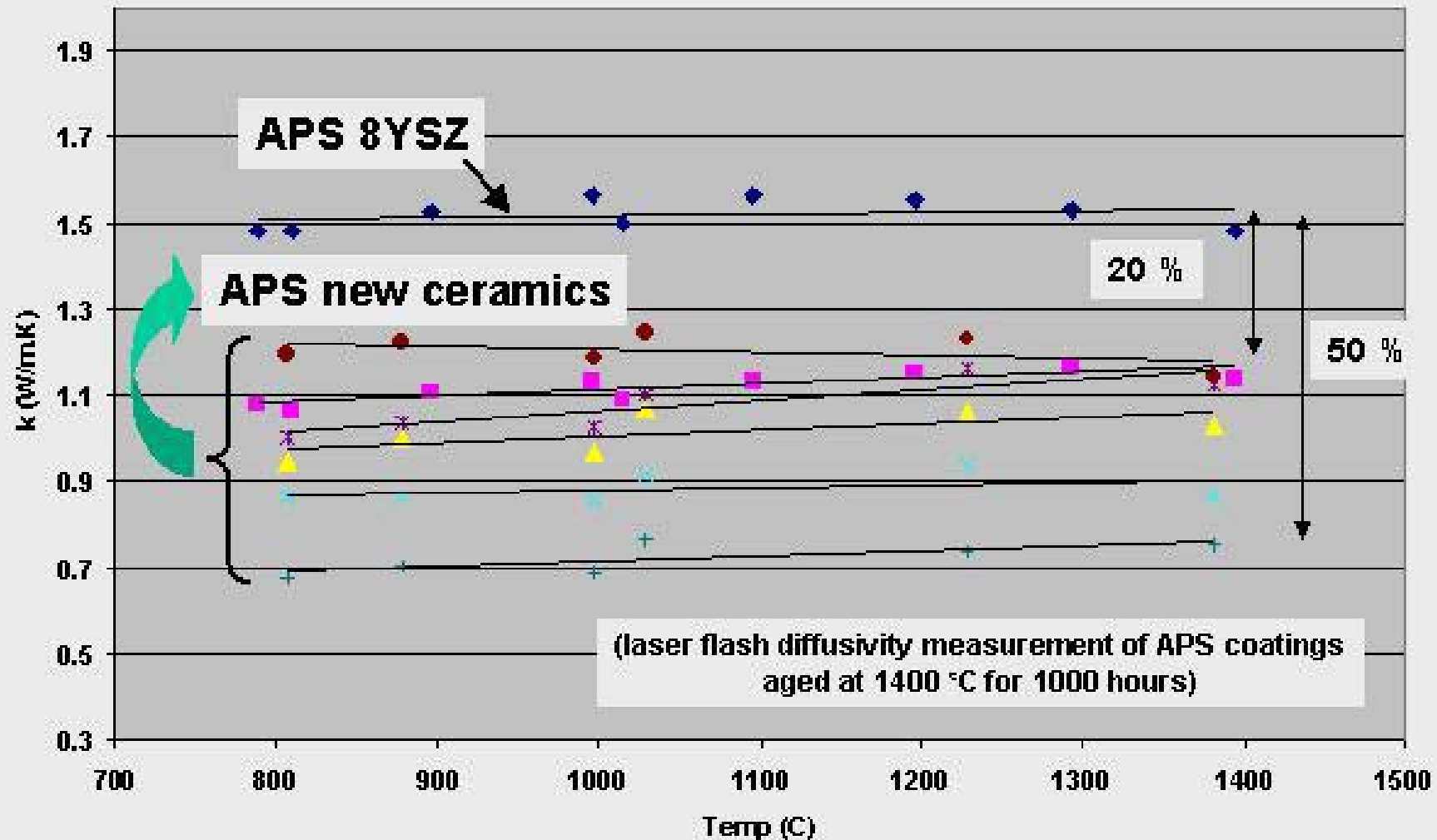


Sintering resistances of new phase stable ceramic compositions were confirmed by dilatometry



(HTML, Oak Ridge National Laboratory)

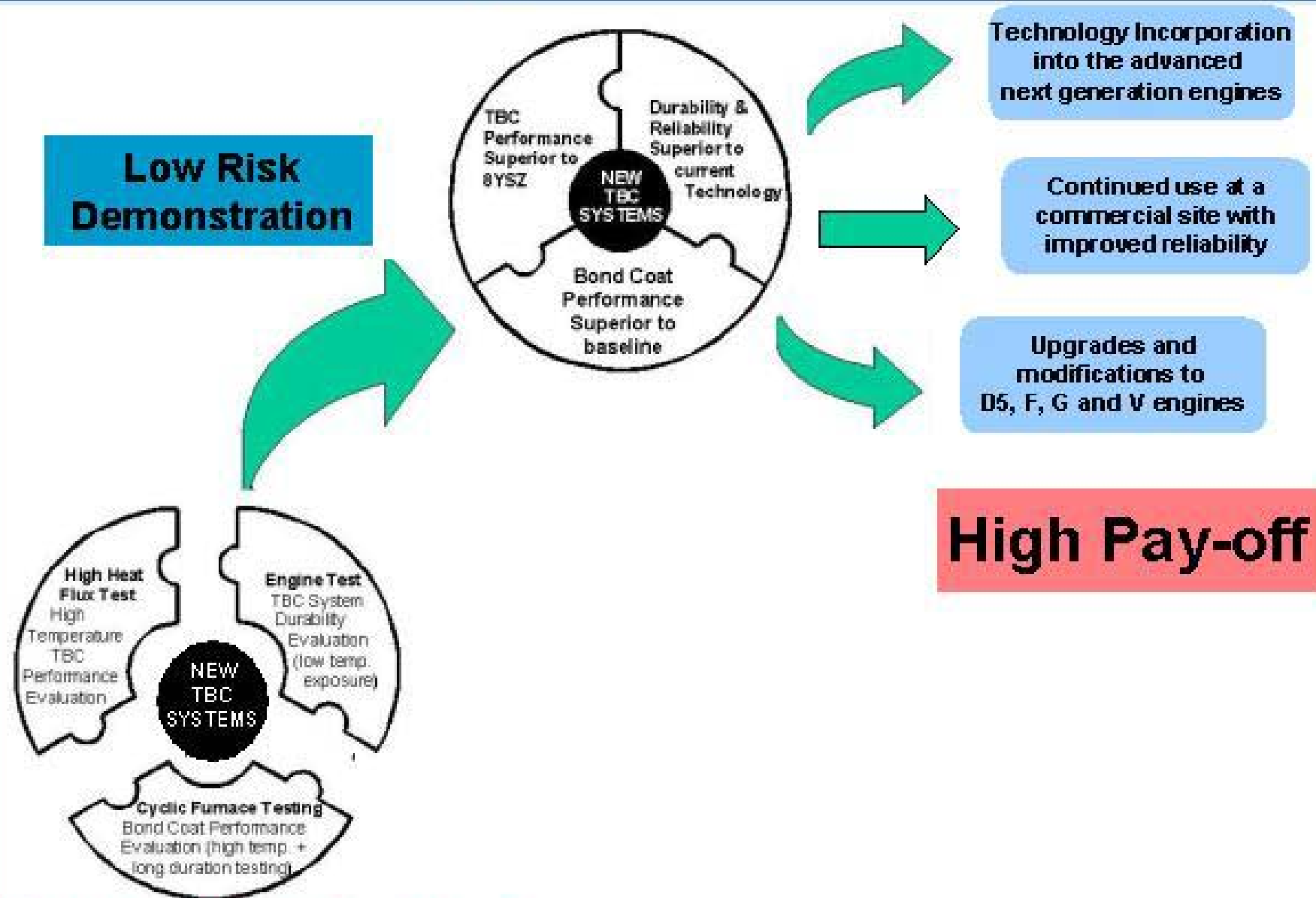
New ceramic compositions have thermal conductivity values 20 % to 50 % lower than APS 8YSZ

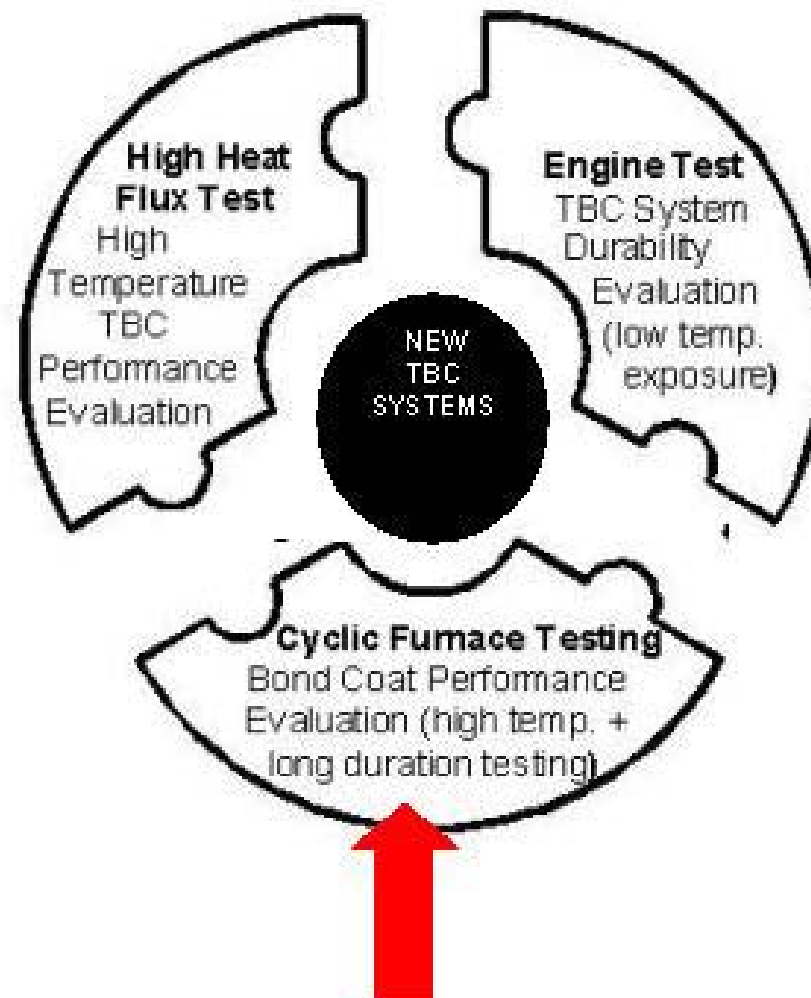


Potential for significant cooling air reduction and increase in engine efficiency

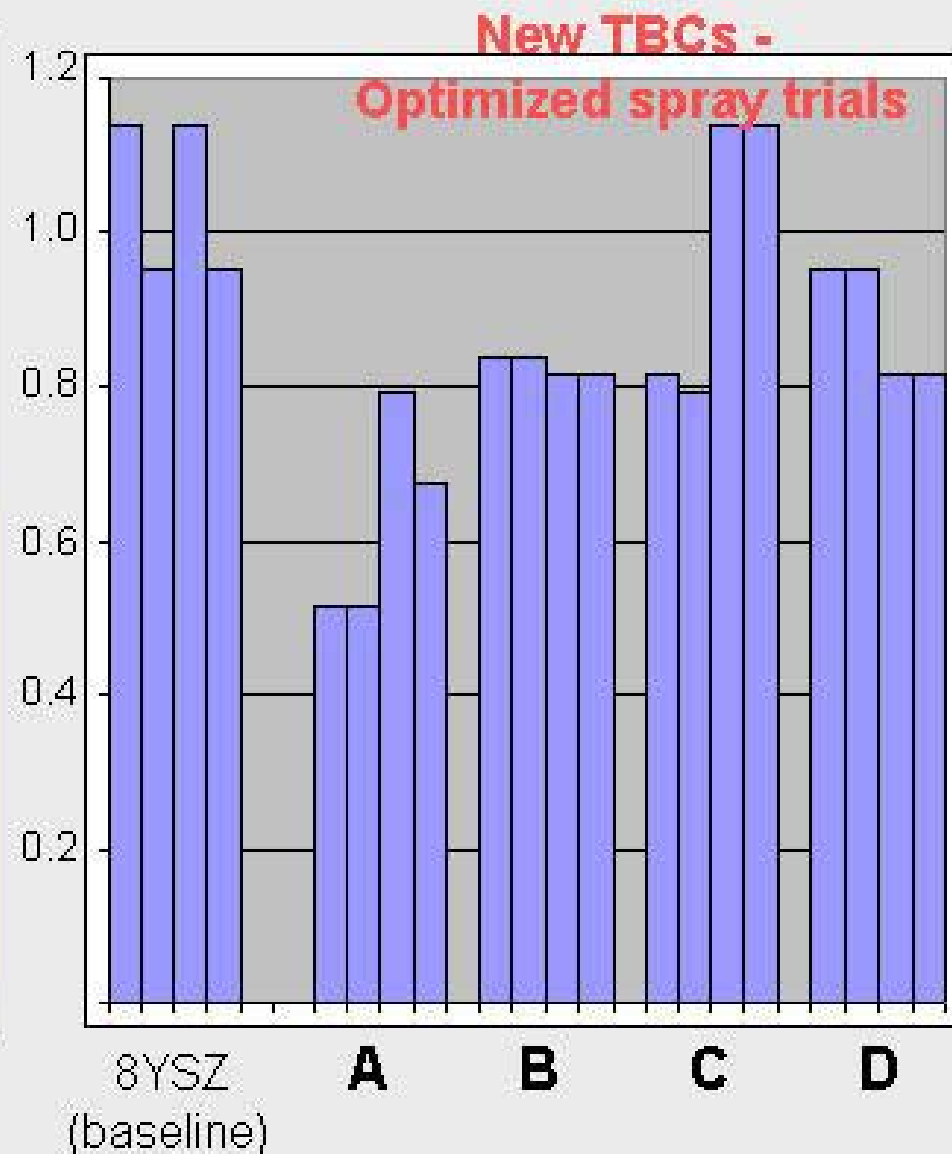
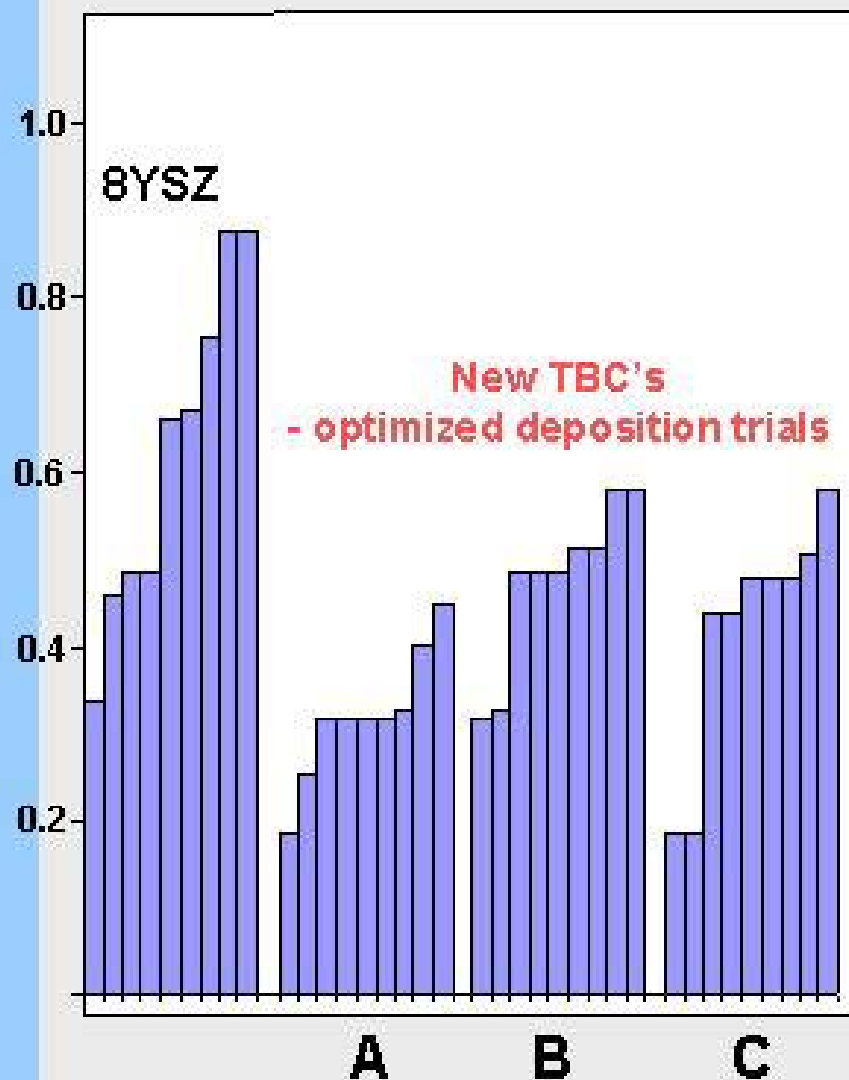
(HTML, Oak Ridge National Laboratory)

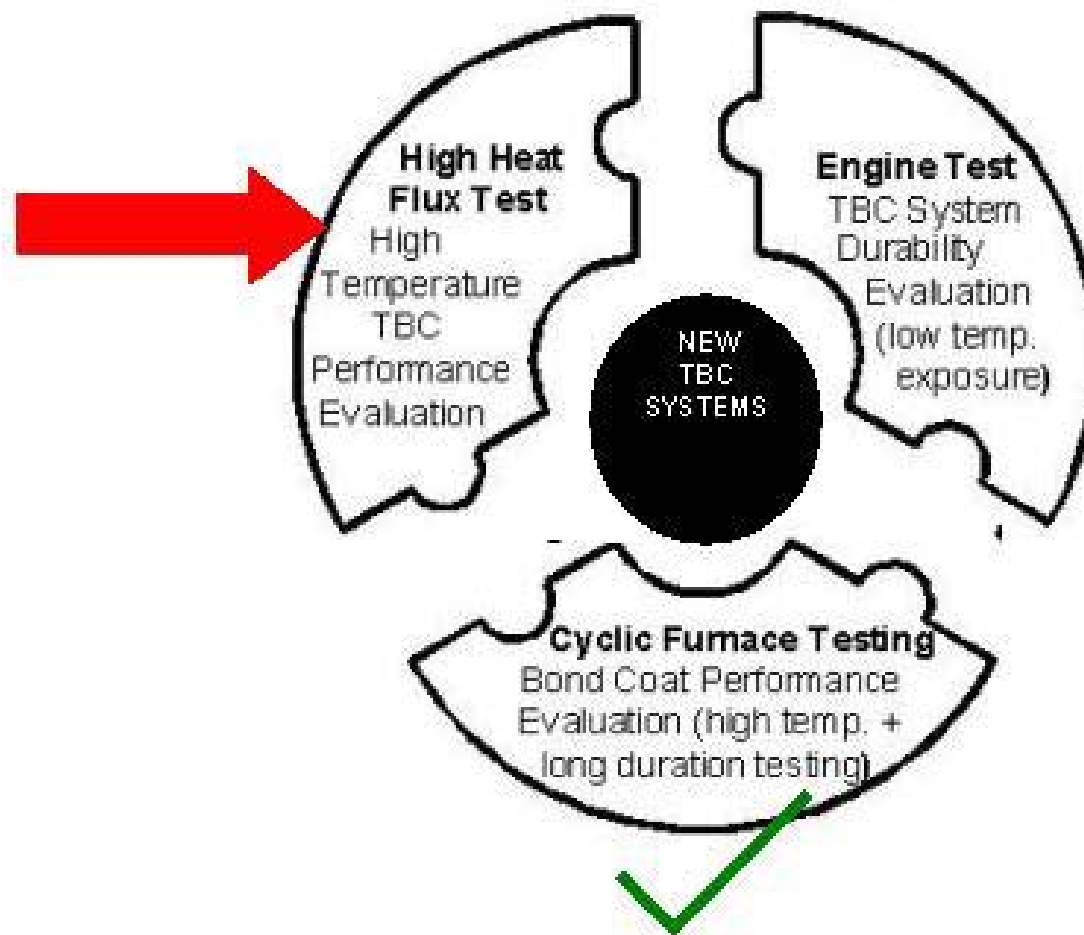
Overview of the technical approach to incorporate advanced technology into our IGT fleet





Optimized deposition parameters were identified for both APS and PVD new TBCs

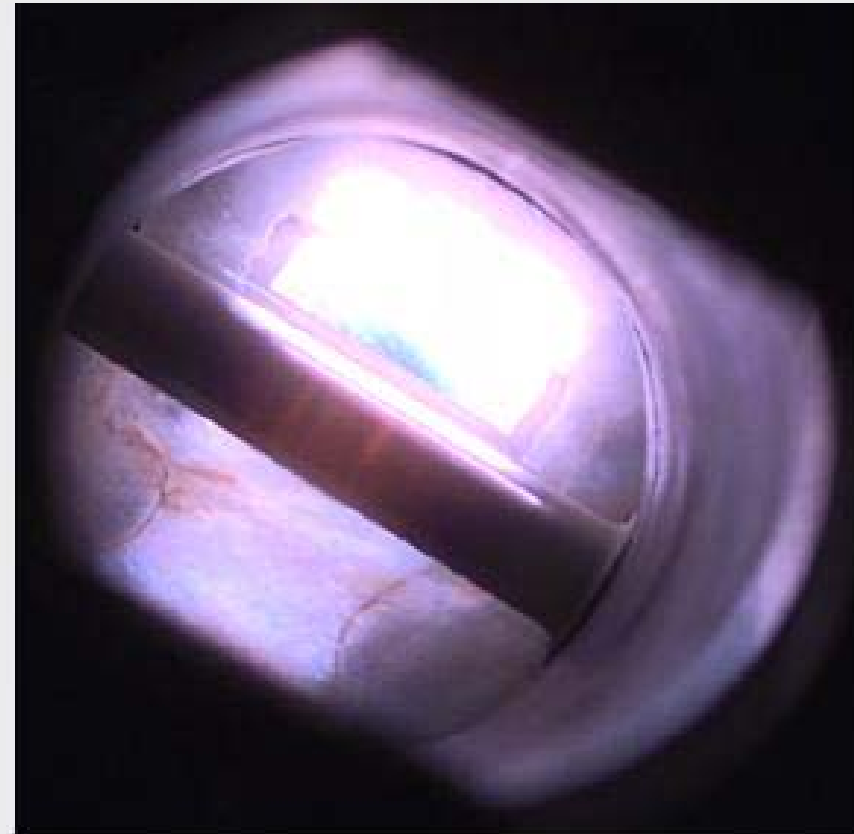




A high heat flux rig, at Waltz Mill, PA, exposes samples to severe thermal gradients

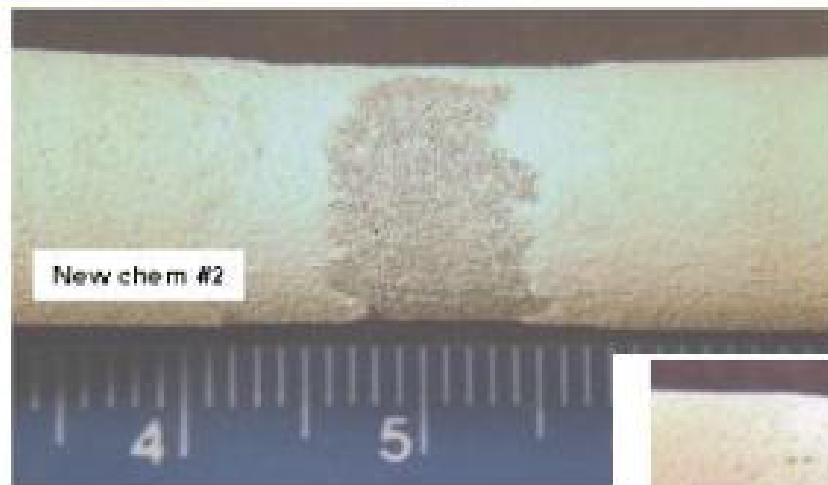
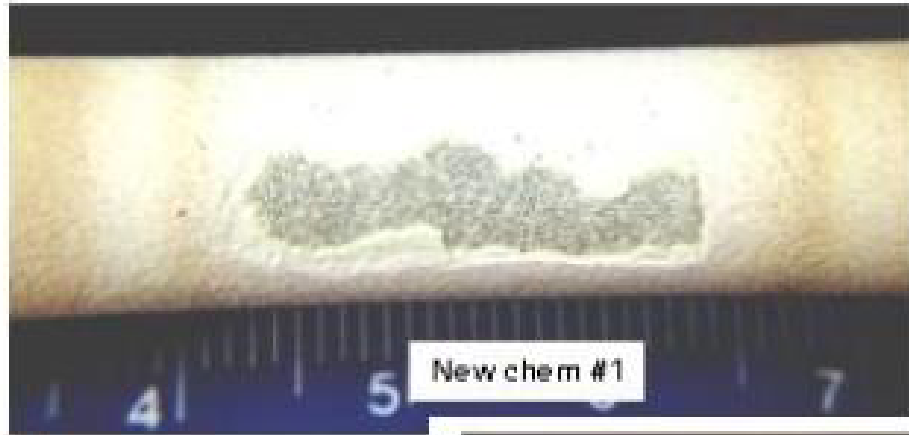
Capabilities

- no contamination of sample
- single rotating tubular sample with thermal barrier coating
 - EB-PVD
 - APS
- maximum surface temperature:
> 1350 °C
- thermal gradient through thickness:
 $\Delta T / \Delta h > 1^\circ\text{C} / \mu\text{m}$
- thermal cycling capabilities
(3 min. - 480+ min.)

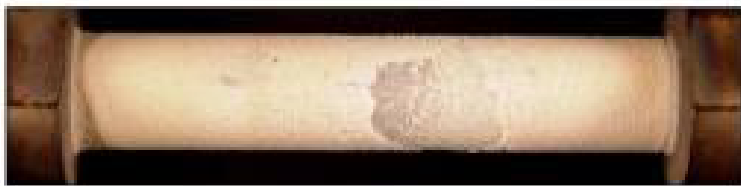


(Westinghouse Plasma Center, PA)

TBC spallation time and failure mechanisms allow for establishing the relative benefits of the different compositions



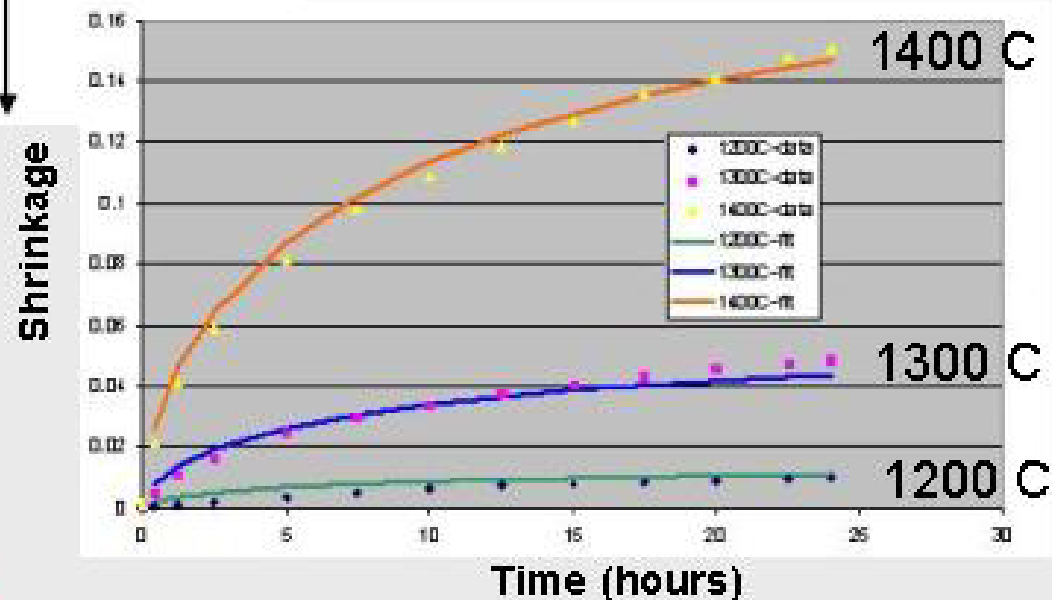
For a given composition, preliminary life prediction models relate TBC spallation time to sintering kinetics



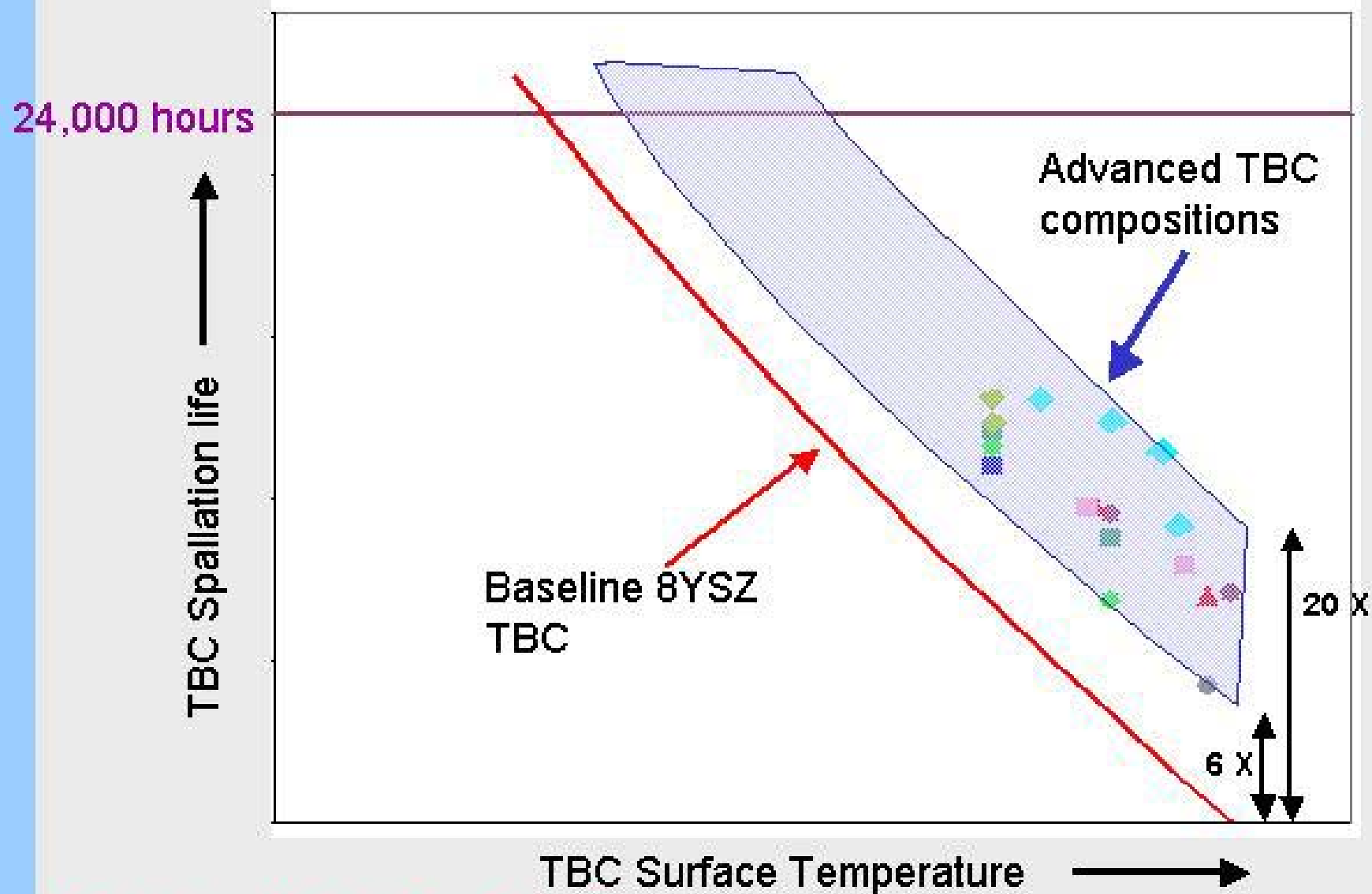
Increasing
Surface
Temperatures

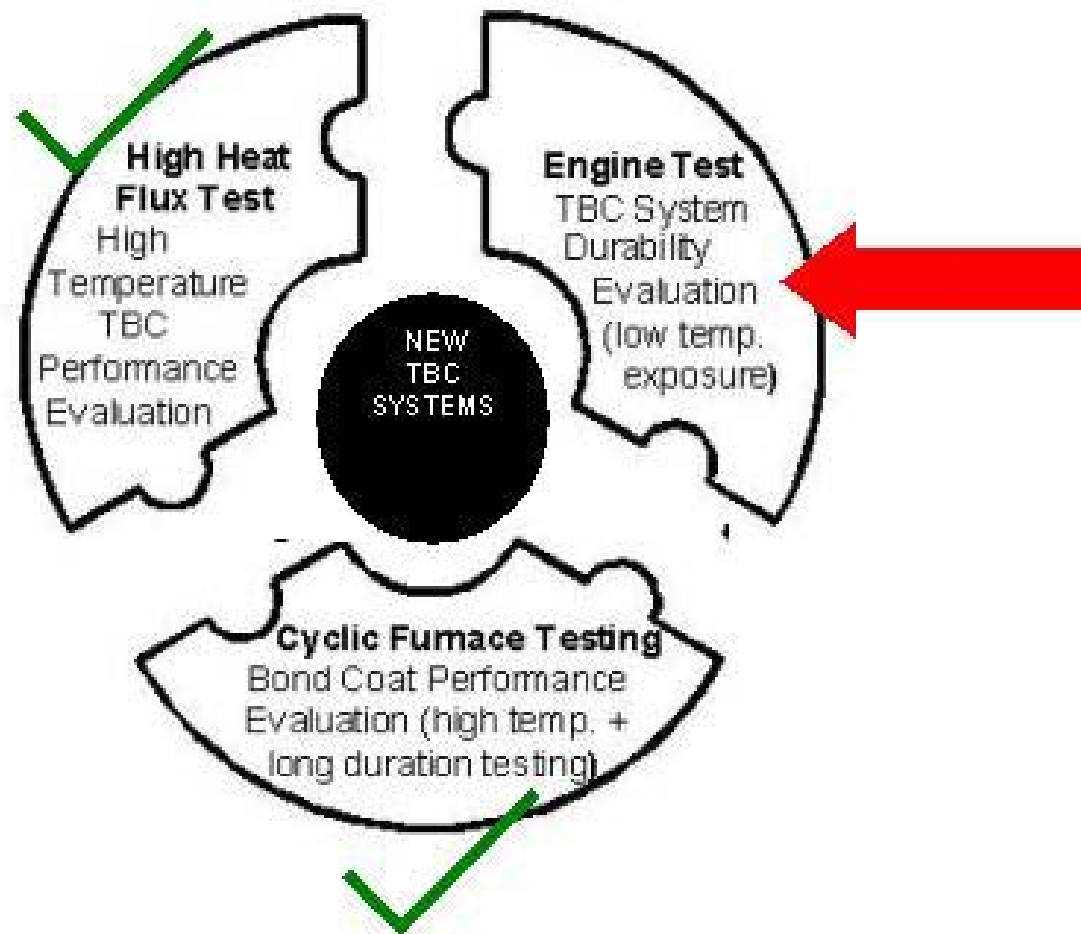
Sintering kinetics

Life prediction of advanced
TBC systems is still in the
very early stages



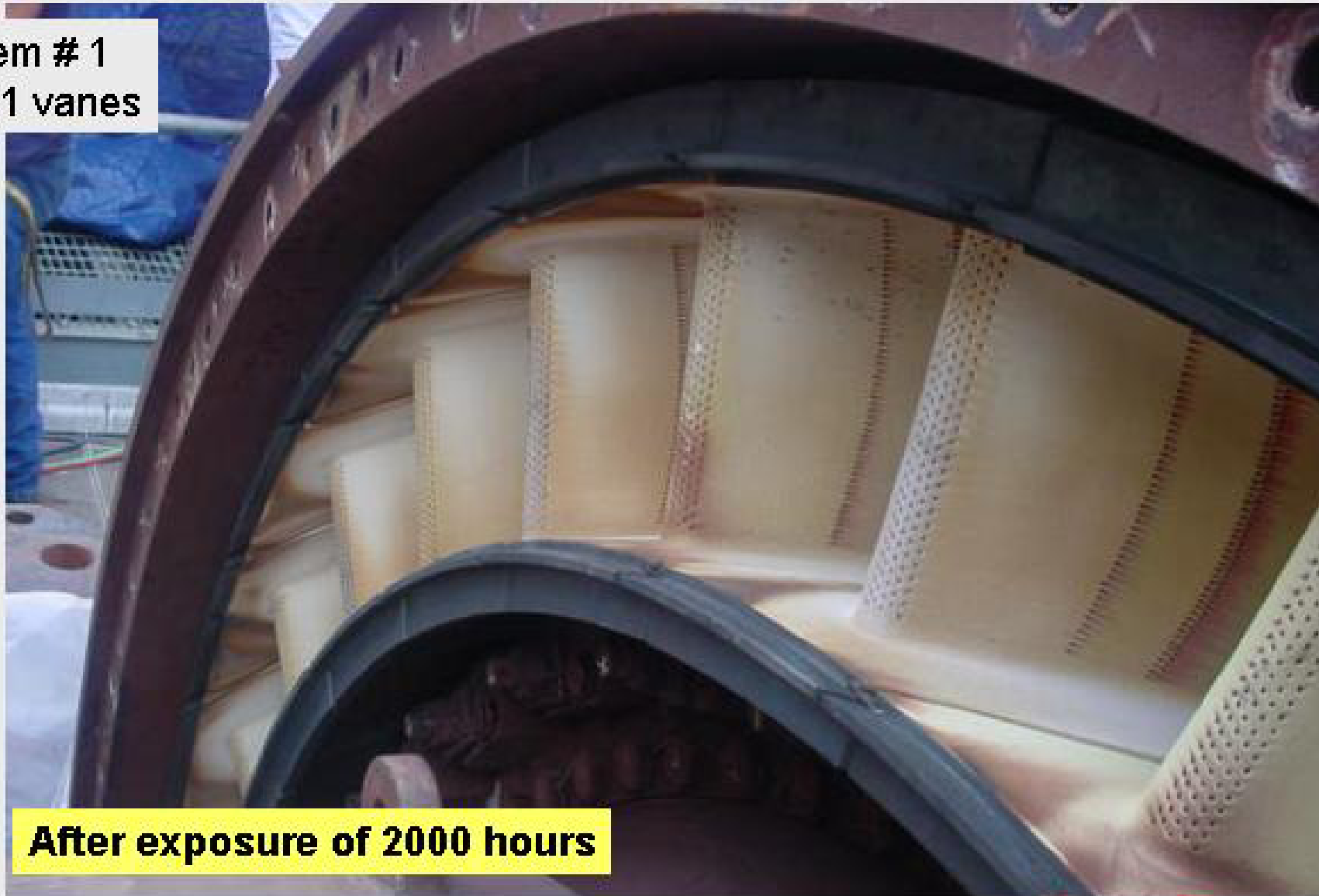
High heat flux testing results show that all compositions have a superior temperature limit than 8YSZ





Eight 50 F Row 1 vanes, with a new TBC composition, were successfully tested in a customer engine

New Chem # 1
on F Row 1 vanes



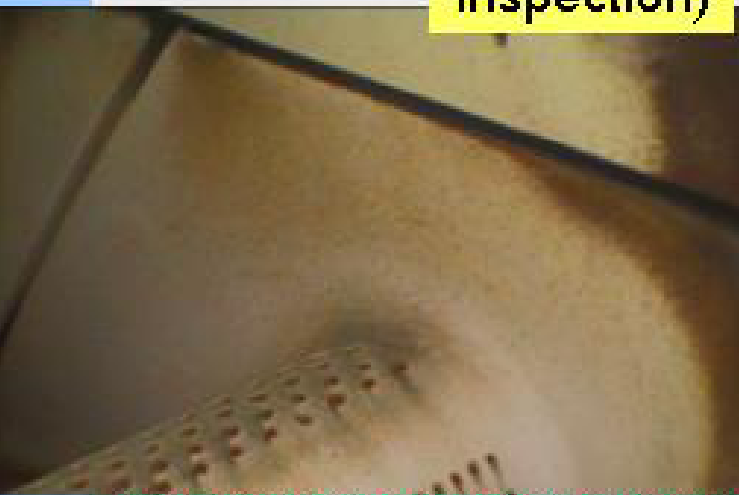
After exposure of 2000 hours

TBC composition, were successfully tested in a customer engine

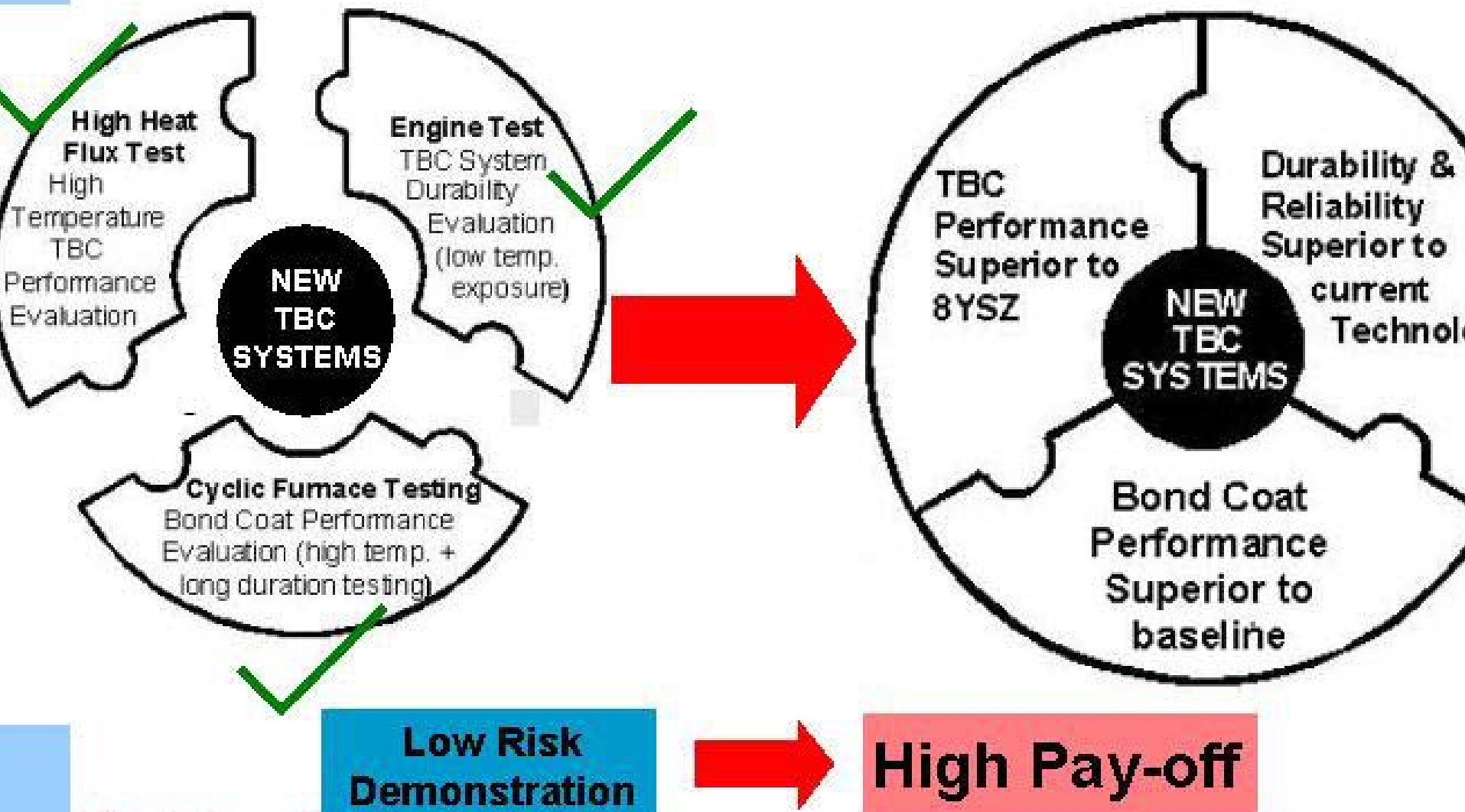
New Chem # 2
on F Row 1 vanes



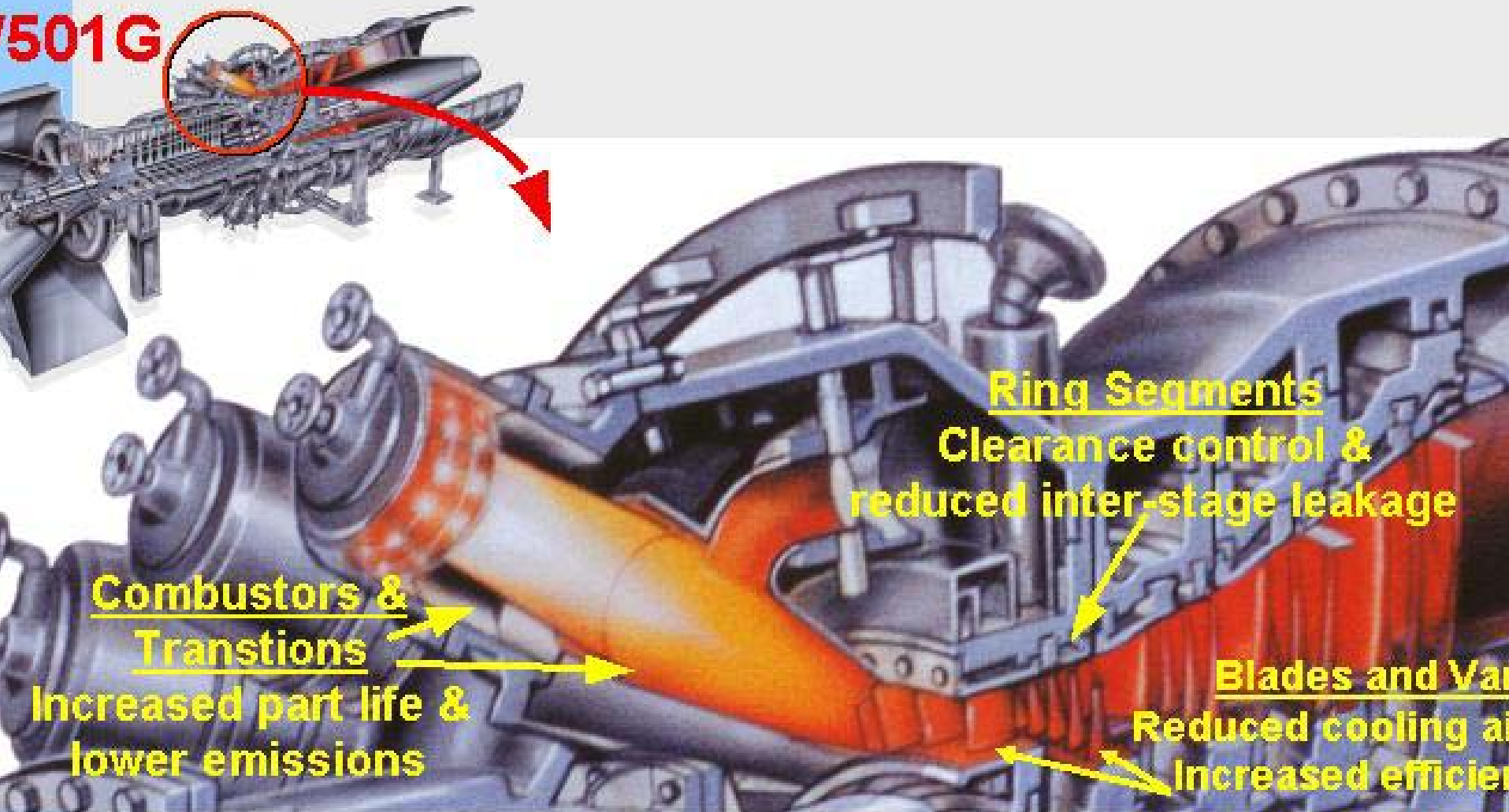
(boroscope
inspection)



Advanced TBC systems are successfully demonstrated for an IGT



Advanced TBCs can significantly impact engine efficiency and performance and component life



advanced thermal barrier coating systems for the next generation engines

- New TBC compositions were successfully down selected and deposited both by APS and EB-PVD
- Sintering resistances and phase stability were shown to be superior to that of the baseline 8YSZ coating
- Cyclic furnace testing showed that TBC spallation from bond coat oxidation met all the requirements
- High heat flux testing proved that superior sintering resistances significantly increased the TBC spallation at high surface temperatures
- Component coatings trials were successfully completed using currently available production equipment
- Coated components were successfully tested in a F engine at a customer site

ADVANCED TBC TECHNOLOGY READY FOR IMPLEMENTATION